# CHAPTER 5

# REFRIGERATION AND AIR CONDITIONING

As an EN3, you have learned the principles of refrigeration and air conditioning; the components and accessories that make up the system; and how to start, operate, and secure refrigeration and air-conditioning plants. As an EN2, you will perform routine maintenance jobs, such as cleaning, lubricating, troubleshooting, servicing the system, using correct procedures for leak detecting, and charging the refrigeration and air-conditioning plants. As you advance in rate, you will be expected to have a greater knowledge of the construction and operating principles of refrigeration and air-conditioning plants. You will be required to perform more complicated maintenance jobs, to make repairs as required, and to determine the causes of inefficient plant operation and accomplish the necessary corrective procedures. This chapter provides some general information on the construction and maintenance of refrigeration and air-conditioning equipment and the detection and correction of operating difficulties.

Refer to the manufacturer's technical manual for details of the plant on your ship. If you have any questions about the basic theory of refrigeration and air conditioning, refer to *EN3,* chapters 16 and 17.

## R-12 REFRIGERATION SYSTEM

We will present the R-12 system as though it had only one evaporator, one compressor, and one condenser. A refrigeration system may (and usually does) include more than one evaporator, and it may include an additional compressor and condenser units.

## COMPRESSORS

Many different types and sizes of compressors are used in refrigeration and air-conditioning systems. They vary from the small hermetic units used in drinking fountains and refrigerators to the large centrifugal units used for air conditioning.

One of the most common compressors on modem ships is a high-speed unit with a variable capacity. This compressor is a multicylinder, reciprocating design with an automatic device built into the compressor to control its output. This automatic capacity control provides for continuous compressor operation under normal load conditions. The capacity of the compressor is controlled by unloading and loading the cylinders. This is a very desirable design feature of the unit. If the compressor had to be started under a load, or with all cylinders working, a much greater amount of torque would be required, and it would be necessary to have a much larger drive motor. Also, if the compressor ran at constant capacity or output, it would reach the low-temperature or low-pressure limits or be constantly starting and stopping, thereby putting excessive work on the unit.

Unloading of the cylinders in the compressor is accomplished by lifting the suction valves off their seats and holding them open. This method of capacity control unloads the cylinders completely but still allows the compressor to work at as little as 25 percent of its rated capacity .

### Unloader Mechanism

When the compressor is not in operation, the unloader mechanism is in the unloaded position as shown in figure 5-1. The mechanism is operated by oil pressure from the capacity control valve. The oil pressure pushes the unloader spring against the unloader piston. This action moves the unloader rod to the left, thereby rotating the cam rings. As the cam rings are rotated, the lifting pins are forced upward, raising the suction valve off its seat. The suction valve is held in this position until the compressor is started and oil pressure of approximately 30 psi is reached. At that time, the oil pressure from the capacity control valve pushes the unloader piston back to the right against the unloader spring. The motion transmitted through the pushrod rotates the cam ring. This lowers the lifting pins and allows the suction valve to close or operate normally and the cylinder to become loaded (fig. 5-2). On most compressors the unloader is connected to the cylinders in pairs.

### Capacity Control Valve

The capacity control valve (fig. 5-3) is located in the compressor crankcase cover. The valve is actuated by oil pressure from the main oil pump. It admits or relieves oil to or from the individual unloader power elements,

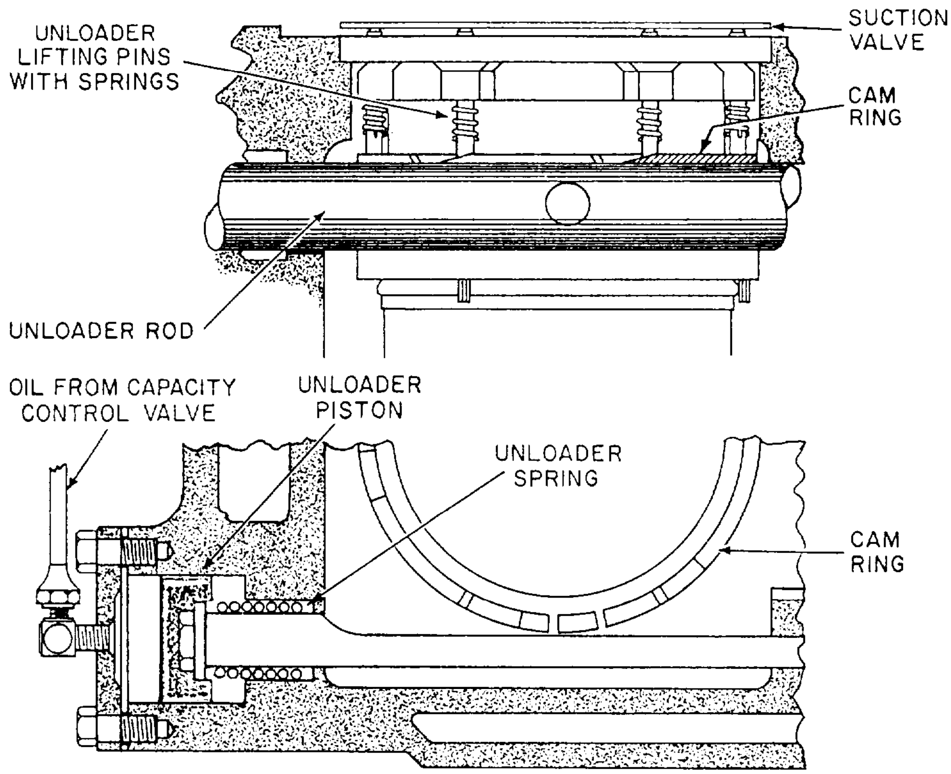



**Figure 5-1.—Unloader mechanism in the unloaded position.**

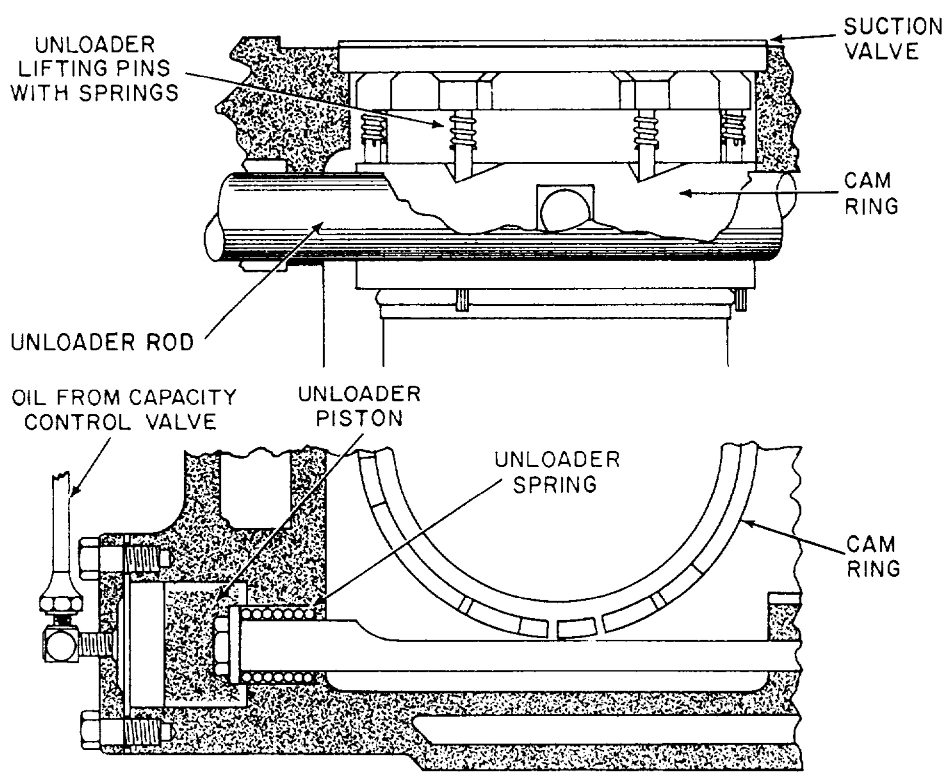



**Figure 5-2.—Unloader mechanism in the loaded position.**

depending on suction or crankcase pressure. Figure 5-3 shows the compressor at rest. The two cylinders equipped with the unloader element are unloaded and will remain unloaded until the compressor is started and the oil pressure reaches normal operating pressure.

The high-pressure oil from the pump enters chamber A of the capacity control valve. It then passes through an orifice in the top of the piston to chamber B, forcing the piston to the end of its stroke against spring A. When the piston of the valve is forced against spring

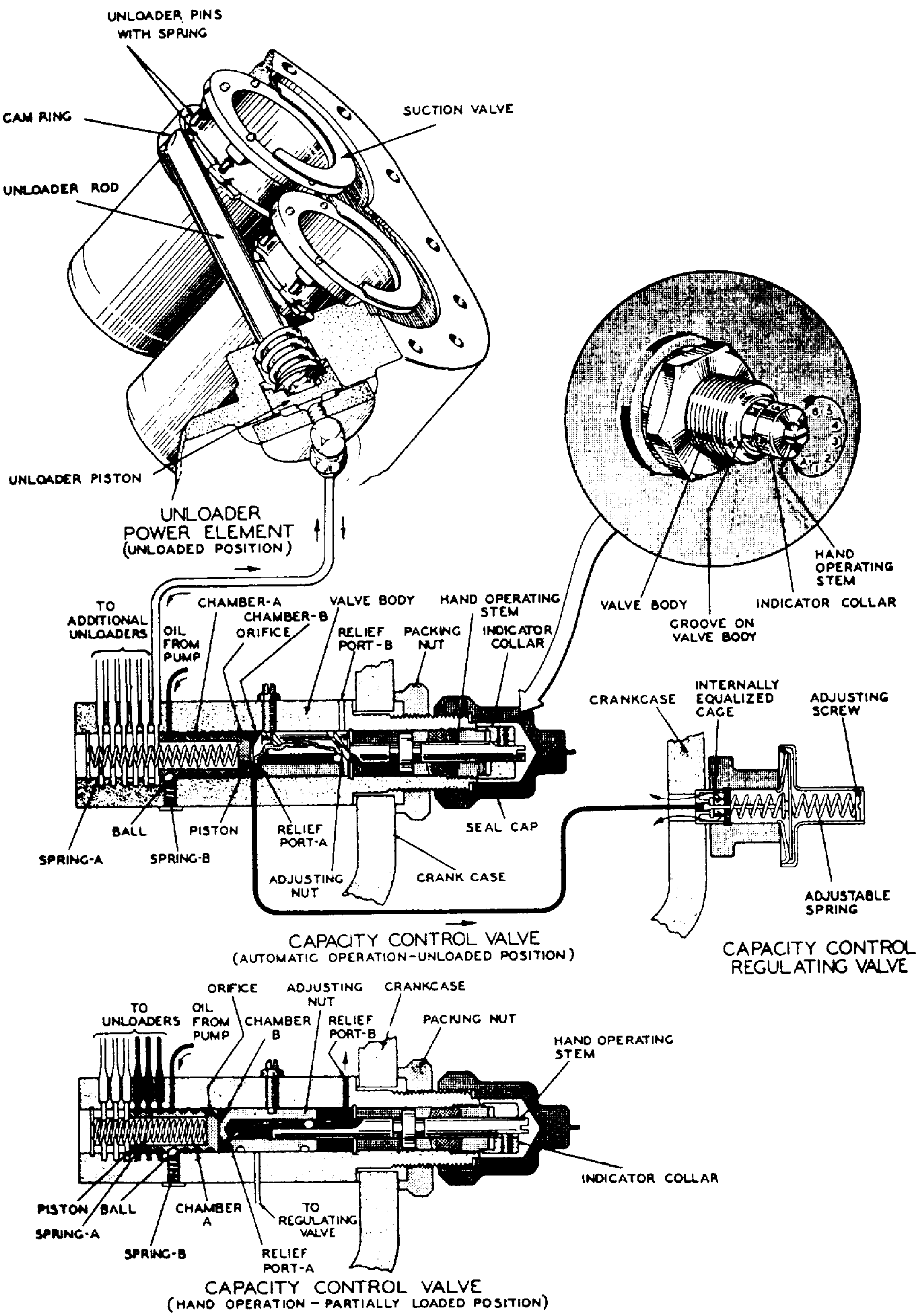



**Figure 5-3.—Capacity control system.**

A, the circular grooves that form chamber A are put in communication with the unloader connections. This admits high-pressure oil to the unloader cylinder and actuates the unloader mechanism.

A capacity control regulating valve controls oil pressure from the capacity control valve. It is connected to the crankcase and has an oil-connecting line to chamber B of the capacity control valve. As the crankcase or suction pressure pulls down slightly below the setting of the regulating valve, the regulator opens and relieves oil pressure from chamber B of the capacity control valve. This permits spring A to push the capacity control piston one step toward chamber B, uncovering the unloader connection nearest the end of the capacity control valve. This relieves oil pressure from the power element and allows the power element spring to rotate the cam rings and unload the cylinder.

If the suction pressure continues to drop, the regulator will relieve more oil pressure and unload more cylinders. If the heat load increases, the suction pressure will increase, causing the regulating valve to close and load more cylinders.

## MAINTENANCE

As an Engineman, maintaining the refrigeration and air-conditioning plants may be one of your responsibilities. To do this, you must understand the maintenance procedures. In most instances, personnel who are assigned to maintain refrigeration plants are graduates of the Navy's air-conditioning and refrigeration school. This school teaches most operating and maintenance procedures. However, you should refer to the manufacturer's technical manuals for the details of the plants on your ship.

### Testing Suction and Discharge Valves

Faulty compressor valves may be indicated by either a gradual or a sudden decrease in the normal compressor capacity. Either the compressor will fail to pump, or the suction pressure cannot be pumped down to the designed value, and the compressor will run for abnormally long intervals or continuously. You may get a rapid buildup of suction (crankcase) pressure during an off cycle. This causes the compressor to start after a very short off-period and indicates leaking discharge valves.

If the refrigeration plant is not operating satisfactory, you should first shift the compressors and then check the operation of the plant. If the operation of the plant is satisfactory when the compressors have been shifted, the trouble is in the compressor and not in the system.

To test the compressor discharge valves, pump down the compressor to 2 psig. Then stop the compressor and quickly close the suction and discharge line valves. If the discharge pressure drops at a rate in excess of 3 pounds in a minute and the crankcase suction pressure rises, this is evidence of compressor discharge valve leakage. If you must remove the discharge valves with the compressor pumped down, open the connection to the discharge pressure gauge to release discharge pressure on the head. Then remove the compressor top head and discharge valve plate. Be careful not to damage the gaskets.

If the discharge valves are defective, replace the entire discharge valve assembly. Any attempt to repair them would probably involve relapping and would require highly specialized equipment. Except in an emergency, such repair should never be undertaken aboard ship.

You can check the compressor internal suction valves for leakage by following these steps:

1. Start the compressor by using the manual control switch on the motor controller.

2. Close the suction line stop valve gradually to prevent violent foaming of the compressor crankcase lubricating oil charge.

3. With this stop valve closed, pump a vacuum of approximately 20 in.Hg. If this vacuum can be readily obtained, the compressor suction valves are satisfactory.

Do not expect the vacuum to be maintained after the compressor stops, because the refrigerant is being released from the crankcase oil. Do not check the compressor suction valve efficiency of operation for at least 3 days. It may be necessary for the valves to wear in.

However, if any of the compressor suction valves are defective, you can pump down the compressor, open it, and inspect the valves. Replace defective valves or pistons with spare assemblies.

### Crankcase Seal Repairs

There are several types of crankcase seals, depending on the manufacturer. On reciprocating compressors, the crankshaft extends through the compressor housing to provide a mount for the pulley wheel or flexible coupling. Now the shaft must be sealed to prevent leakage of lubricating oil and refrigerant. The crankshaft seal is bathed in lubricating oil at a pressure equal to the suction pressure of the refrigerant. The first indication of crankshaft seal failure is excessive oil leaking at the shaft.

When the seal must be replaced or when it shows signs of abnormal wear or damage to the running surfaces, a definite reason can be found for the abnormal conditions. Make an inspection to locate and correct the trouble, or the failure will recur.

Seal failure is very often caused by faulty lubrication, usually because of the condition of the crankcase oil. A dirty or broken oil seal is generally caused by one or both of the following conditions:

– Dirt or foreign material is in the system or system piping. Dirt frequently enters the system at the time of installation. After a period of operation, foreign material will accumulate in the compressor crankcase, tending to concentrate in the oil chamber surrounding the shaft seal. When the oil contains grit, it is only a matter of time until the highly finished running faces become damaged, causing failure of the shaft seal.

– Moisture is frequently the cause of an acid condition of the lubricating oil. Oil in this condition will not provide satisfactory lubrication and will cause failure of the compressor parts. Use a refrigerant dehydrator when the compressor is put into operation if you suspect that moisture may be a problem. Anytime foreign material is found in the lubricating oil, thoroughly clean the entire system (piping, valves, and strainers).

**REMOVING A SHAFT SEAL.—**If a shaft seal must be removed, proceed as follows:

If the seal is broken to the extent that it permits excessive oil leakage, do NOT attempt to pump the refrigerant out of the compressor. If you do, air containing moisture will be drawn into the system through the damaged seal. Moisture entering the refrigerant system may cause expansion valves to freeze. This can cause acid formation and other problems. If oil is leaking excessively, close the compressor suction and discharge valves and relieve the pressure to the atmosphere by loosening a connection on the compressor discharge gauge line.

Next, drain the oil from the compressor crankcase. Since the oil contains refrigerant, it will foam while being drained. Leave the oil drain valve or plug open while you are working on the seal. This ensures that refrigerant escaping from the oil remaining in the crankcase will not build up pressure and blow out the seal while it is being removed.

Remove the compressor flywheel (or coupling) and carefully remove the shaft seal assembly. If the assembly cannot be readily removed, build up a slight pressure in the compressor crankcase. To do this, slightly open the compressor suction valve. Take the necessary precautions to support the seal and to prevent it from being blown from the compressor and damaged.

**INSTALLING A SHAFT SEAL.—**Clean and replace the entire seal assembly according to the manufacturer's instructions.

Wipe the shaft clean with a linen or silk cloth; do not use a dirty or lint-bearing cloth. Be careful not to touch the bearing surfaces with your hands as you unwrap the seal. Rinse the seal in an approved solvent and allow it to air-dry. (Do NOT wipe the seal dry!) Dip the seal in clean refrigerant oil. Follow the instructions found in the manufacturer's technical manual to insert the assembly. Bolt the seal cover in place and tighten the bolts evenly. Replace the flywheel and belts or coupling and check and correct the motor and compressor shaft alignment. To test the unit for leaks, open the suction and discharge valves and use a halide leak detector.

### Evacuating the Compressor

Whenever repairs to a compressor allow any appreciable amount of air to enter the unit, the compressor should be evacuated after assembly is completed and before it is ready for operation The proper procedure is as follows:

1. Disconnect a connection in the compressor discharge gauge line between the discharge line stop valve and the compressor.

2. Start the compressor and let it run until the greatest possible vacuum is obtained.

3. Stop the compressor and immediately open the suction stop valve slightly. This will blow refrigerant through the compressor valves and purge the air above the discharge valves through the open gauge line.

4. Close the discharge gauge line and open the discharge line stop valve.

5. Remove all oil from the exterior of the compressor.

6. Test the compressor joints for leakage using the halide leak detector.

### Cleaning Suction Strainers

When putting a new unit into operation, you should clean the suction strainers after a few hours of operation. Refrigerants have a solvent action and will loosen any foreign matter in the system. This foreign matter will eventually reach the suction strainers. After a few days of operation, the strainers will need another cleaning. Inspect them frequently during the first few weeks of plant operation and clean as necessary.

The suction strainers are located in the compressor housing or in the suction piping. The procedure for cleaning the strainers is as follows:

1. Pump down the compressor.

2. Remove the strainer and inspect it for foreign matter.

3. Dip the strainer screen in an approved solvent and allow it to dry.

4. Replace the strainer and evacuate the air from the compressor.

5. Test the housing for leaks by wiping up all oil and then using a halide leak detector.

Maintenance Precautions

Sometimes a compressor cannot be pumped down and is damaged to the extent that it has to be opened for repairs. If so, you should first close the suction and discharge valves. Then allow all refrigerant in the compressor to vent to the atmosphere through a gauge line.

When you must remove, replace, or repair internal parts of the compressor, observe the following precautions:

1. Carefully disassemble and remove parts; note the correct relative position so that errors will not be made when you reassemble.

2. Inspect all parts that become accessible.

3. Make certain that all parts and surfaces are free of dirt and moisture.

4. Freely apply clean compressor oil to all bearing and rubbing surfaces of parts being replaced or reinstalled.

5. If the compressor is not equipped with an oil pump, make certain that the oil dipper on the lower connecting rod is in the correct position for dipping oil when the unit is in operation.

6. Position the ends of the piston rings so that alternate joints are on the opposite side of the piston

7. Take care not to score gasket surfaces.

8. Replace all gaskets.

9. Clean the crankcase and replace the oil.

## CONDENSERS

The compressor discharge line terminates at the refrigerant condenser. In shipboard installations, these condensers are usually of the multipass shell-and-tube type, with water circulating through the tubes. The tubes are expanded into grooved holes in the tube sheet to make a tight joint between the shell and the circulating water. Refrigerant vapor is admitted to the shell and condenses on the outer surfaces of the tubes.

Any air or noncondensable gases that may accidentally enter the refrigeration system will be drawn through the piping and eventually discharged into the condenser with the refrigerant. The air or noncondensable gases accumulated in the condenser are lighter than the refrigerant gas. They will rise to the top of the condenser when the plant is shut down. A purge valve, for purging the refrigeration system (when necessary), is installed at the top of the condenser or at a high point in the compressor discharge line.

### Cleaning Condenser Tubes

To clean the condenser tubes properly, first drain the cooling water from the condenser. Then disconnect the water connections and remove the condenser heads. Be careful not to damage the gaskets between the tube sheet and the waterside of the condenser heads. Inspect tubes as often as practical and clean them as necessary, using an approved method. Use rubber plugs and an air lance or a water lance to remove foreign deposits. You must keep the tube surfaces clear of particles of foreign matter. However, you must not destroy the thin protective coating on the inner surfaces of the tubes. If the tubes become badly corroded, replace them. Replacement avoids the possibility of losing the charge and admitting salt water to the system.

### Cleaning Air-Cooled Condensers

Although the large plants are equipped with water-cooled condensers, auxiliary units are commonly provided with air-cooled condensers. The use of air-cooled condensers eliminates the necessity for circulating water pumps and piping.

Keep the exterior surface of the tubes and the fins on an air-cooled condenser free of dirt or any matter that might obstruct heat flow and air circulation. The finned surface should be brushed clean with a stiff bristle brush as often as necessary. Low-pressure air is very useful in removing dirt in hard-to-reach places on condensers. When installations are exposed to salt spray and rain through open doors or hatches, you should take steps to minimize corrosion of the exterior surfaces.

### Testing For Leaks

To prevent serious loss of refrigerant through leaky condenser tubes, test the condenser for leakage by following the PMS.

To test for leaky condenser tubes, drain the waterside of the condenser. Then insert the exploring tube of the leak detector through one of the drain plug openings. If this test indicates that Freon gas is present, you can find the exact location of the leak by following these steps:

1. Remove the condenser heads.

2. Clean and dry the tube sheets and the ends of the tubes.

3. Check both ends of each tube with a leak detector. Mark any tubes that show leakage. If you cannot determine that a tube is leaking internally or around the tube sheet joint, plug the suspected tube and again check around the tube sheet joint. Mark the adjacent tube, if necessary, to isolate the suspected area.

4. To locate or isolate very small leaks in the condenser tubes, hold the exploring tube at one end of the condenser tube for about 10 seconds to draw fresh air through the tube. Repeat this procedure with all the tubes in the condenser. Allow the condenser tubes to remain plugged for 4 to 6 hours; then, remove the plugs one at a time and check each tube for leakage. If a leaky tube is detected, replace the plug immediately to reduce the amount of refrigerant escaping. Make appropriate repairs or mark and plug all leaky tubes for later repairs.

### Plugging or Retubing Condensers

The general procedures for plugging or retubing condensers can be found in *Naval Ship's Technical Manual (NSTM)*, Chapter 254, “Condensers, Heat Exchangers, and Air Ejectors.” When plugging or retubing a specific condenser, follow the procedures in the manufacturer’s technical manual.

## THERMOSTATIC EXPANSION VALVES

The thermostatic expansion valve is essentially a reducing valve between the high-pressure side and the low-pressure side of the system. The valve is designed to proportion the rate at which the refrigerant enters the cooling coil to the rate of evaporation of the liquid refrigerant in the coil; the amount depends, of course, on the amount of heat being removed from the refrigerated space.

When the thermostatic expansion valve is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter.

Once a valve is properly adjusted, further adjustment should not be necessary. The major trouble can usually be traced to moisture or dirt collecting at the valve seat and orifice.

### Testing and Adjustment

The thermostatic expansion valves used in most shipboard systems can be adjusted by means of a gear and screw arrangement to maintain a superheat ranging from about 4°F to 12°F at the cooling coil outlet. The proper superheat adjustment varies with the design and service operating conditions of the valve and the design of the particular plant. Increased spring pressure increases the degree of superheat at the coil outlet. Decreased spring pressure decreases the degree of superheat at the coil outlet.

Some thermostatic expansion valves have a fixed (nonadjustable) superheat. These valves are used primarily in self-contained equipment where the piping configuration and evaporating conditions are constant.

If expansion valves are adjusted to give a high superheat at the coil outlet or if the valve is stuck shut, the amount of refrigerant admitted to the cooling coil will be reduced. With an insufficient amount of refrigerant, the coil will be “starved” and will operate at a reduced capacity. Also, the velocity of the refrigerant through the coil may not be adequate to carry oil through the coil. This robs the compressor crankcase and provides a condition where slugs of lubricating oil may be drawn back into the compressor. If the expansion valve is adjusted for too low a degree of superheat or if the valve is stuck open, liquid refrigerant may flood from the cooling coils back into the compressor. When liquid refrigerant collects at a low point in the suction line or coil and is drawn back into the compressor intermittently in slugs, there is danger of injury to the moving parts of the compressor.

In general, the expansion valves for air-conditioning and water-cooling plants (high-temperature installations) normally are adjusted for higher superheat than the expansion valves for cold storage refrigeration and ship's service store equipment (low-temperature installations).

You may not be able to adjust expansion valves to the desired settings, or you may suspect that the expansion valve assembly is defective and requires replacement. In either case, you should make appropriate tests. First you should be sure that the liquid strainers are clean, that the solenoid valves are operative, and that the system is sufficiently charged with refrigerant.

The major pieces of equipment required for expansion valve tests is as follows:

- A service drum of R-12 or a supply of clean, dry air at 70 to 100 psig. The service drum is used to supply gas under pressure. The gas does not have to be the same as that used in the thermal element of the valve being tested.
- A high-pressure and a low-pressure gauge. The low-pressure gauge should be accurate and in good condition so that the pointer does not have any appreciable lost motion. The high-pressure gauge, while not absolutely necessary, will be useful in showing the pressure on the inlet side of the valve. Refrigeration plants are provided with suitable replacement and test pressure gauges.

The procedure for testing is as follows:

1. Connect the valve inlet to the gas supply with the high-pressure gauge attached to indicate the gas pressure to the valve. Connect the low-pressure gauge loosely to the expansion valve outlet. The reason the low-pressure gauge is connected loosely is to allow a small amount of leakage through the connection.

2. Insert the expansion valve thermal element in a bath of crushed ice. Do NOT attempt to perform this test with a container full of water in which a small amount of crushed ice is floating.

3. Open the valve on either the service drum or in the air supply line. Make certain that the gas supply is sufficient to build up the pressure to at least 70 psi on the high-pressure gauge connected in the line to the valve inlet.

4. The expansion valve can now be adjusted. If you want to adjust for 10°F superheat, the pressure on the outlet gauge should be 22.5 psig. This is equivalent to an R-12 evaporating temperature of 22°F. Since the ice maintains the bulb at 32°F. the valve adjustment is for 10°F superheat (difference between 32 and 22). For a 5°F superheat adjustment, the valve should be adjusted to give a pressure of approximately 26.1 psig. There must be a small amount of leakage through the low-pressure gauge connection while this adjustment is being made.

5. To determine if the valve operates smoothly, tap the valve body lightly with a small weight. The low-pressure gauge needle should not jump more than 1 psi.

6. Now tighten the low-pressure gauge connection to stop the leakage at the joint and determine if the expansion valve seats tightly. If the valve is in good condition, the pressure will increase a few pounds and then either stop or build up very slowly. But with a leaking valve, the pressure will build up rapidly until it equals the inlet pressure. With externally equalized valves, the equalizer line must be connected to the piping from the valve outlet to the test gauge to obtain an accurate superheat setting.

7. Again loosen the gauge to permit leakage at the gauge connection. Remove the thermal element, or control bulb, from the crushed ice. Warm it with your hands or place it in water that is at room temperature. When this is done, the pressure should increase rapidly, showing that the power element has not lost its charge. If there is no increase in pressure, the power element is dead.

8. With high pressure readings showing on both gauges, the valve can be tested to determine if the body joints or the bellows leak This can be done by using a halide leak detector. When you perform this test, it is important that the body of the valve have a fairly high pressure applied to it. In addition, the gauges and other fittings should be made up tightly at the joints to eliminate leakage at these points.

**Replacement of Valves**

If the expansion valve is defective, it must be replaced. Most valves used on naval ships have replaceable assemblies. Sometimes it is possible to replace a faulty power element or some other part of the valve without having to replace the entire assembly. When replacement of an expansion valve is necessary, you must replace the unit with a valve of the same capacity and type.

## ADDITIONAL SYSTEM MAINTENANCE

In addition to the maintenance of the components previously described, other parts of the system will need periodic maintenance to keep the plant operating properly.

Vibration may cause leakage in the piping system. This leakage may allow air and moisture to be drawn in or a loss of refrigerant charge. If this happens, the plant operation will become erratic and inefficient, and the cause of trouble must be corrected.

## CHARGING THE SYSTEM

Information concerning the charging of refrigeration systems may be found in *NSTM*, Chapter 516, “Refrigeration System.” The amount of refrigerant charge must be sufficient to maintain a liquid seal between the condensing and evaporating sides of the system. Under normal operating conditions, when the compressor stops, the receiver of a properly charged system is about 85 percent full of refrigerant. The proper charge for a specific system or unit can be found in the manufacturer’s technical manual or on the ship’s blueprints.

A refrigeration system should not be charged if it has leaks or if you have a reason to believe the system has a leak. The leaks must be found and corrected. Immediately following-or during-the process of charging, you should carefully check the system for leaks.

A refrigeration system must have an adequate charge of refrigerant at all times; otherwise, its efficiency and capacity will be impaired.

## PURGING THE SYSTEM

To determine if the system contains noncondensable gases, operate the system for 30 minutes. Stop the compressor for 10 to 15 minutes, leaving all the valves in their normal positions. Observe the pressure and temperature as indicated on the high-pressure gauge. Read the thermometer in the liquid line, or read the temperature of the cooling water discharge from the condenser. Compare the temperature reading with the temperature conversion figures shown on the discharge pressure gauge. If the temperature of the liquid leaving the receiver is more than 5°F lower than the temperature corresponding to the discharge pressure, the system should be purged. Pump the system down and secure the compressor; then open the purge valve on the condenser. Purge very slowly, at intervals, until the air is expelled from the system and the temperature difference drops below 5°F.

## CLEANING LIQUID LINE STRAINERS

Where a liquid line strainer is installed, it should be cleaned at the same intervals as the suction strainer. If a liquid line strainer becomes clogged to the extent that it needs cleaning, a loss of refrigeration will take place. The tubing on the outlet side of the strainer will be much colder than the tubing on the inlet side.

To clean the liquid line strainer, secure the receiver outlet valve and wait a few minutes to allow any liquid in the strainer to flow to the cooling coils. Then close the strainer outlet valve and very carefully loosen the cap that is bolted to the strainer body. (Use goggles to protect your eyes!) When all the pressure is bled out of the strainer, remove the cap and lift out the strainer screen. Clean the strainer screen with an approved solvent and a small brush. Reinstall the spring and screen in the strainer body; then replace the strainer cap loosely. Purge the air out of the strainer by blowing refrigerant through it; then tighten the cap. After the assembly is complete, test the unit for leaks.

## CLEANING OIL FILTERS AND STRAINERS

Compressors arranged for forced-feed lubrication have lubricating oil strainers in the suction line of the lube-oil pump. An oil filter may be installed in the pump discharge line. A gradual decrease in lubricating oil pressure indicates that these units need cleaning. This cleaning is done in much the same manner as described for cleaning suction strainers.

When cleaning is necessary, drain the lubricating oil in the crankcase from the compressor. Add a new charge of oil, equal to the amount drained, before restarting the unit. When the compressor is put back into operation, adjust the lube-oil pressure to the proper setting by adjusting the oil pressure regulator.

## MAINTAINING COOLING COILS

You should inspect the cooling coils regularly and clean them as required. Defrost the cooling coils as often as necessary to maintain the effectiveness of the cooling surface. Excessive buildup of frost on the cooling coils will result in reduced capacity of the plant, low compressor suction pressure, and a tendency for the compressor to short-cycle. The maximum time interval between defrostings depends on such factors as condition of door gaskets, moisture content of supplies placed in boxes, frequency of opening doors, atmospheric humidity, and refrigerant evaporating temperatures.

You should always defrost the cooling coils before the frost thickness reaches three-sixteenths of an inch. When defrosting the coils, be sure that you do NOT try to scrape or break the frost off. Improper defrosting will cause serious damage to the coils.

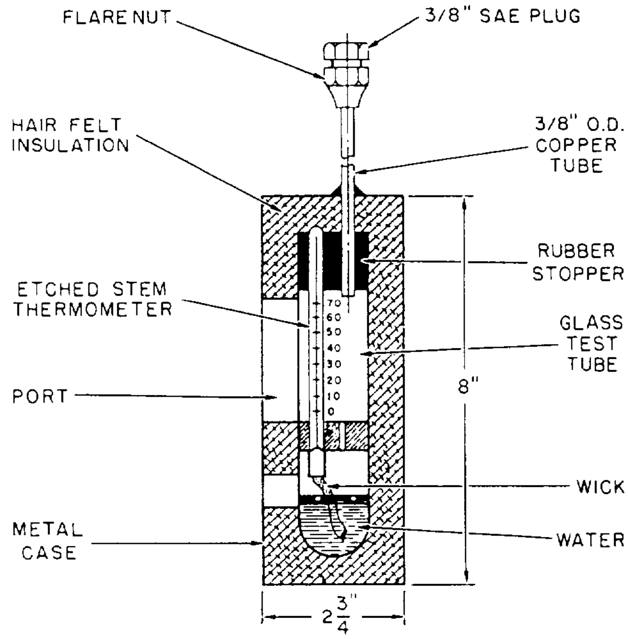
## EVACUATING AND DEHYDRATING THE SYSTEM

In areas where moisture accumulation must be corrected, the system should first be cleared of refrigerant and air. The time required will depend upon the size of the system and the amount of moisture present. It is a good engineering practice to circulate heated air through a large dehydrator system for several hours, or as long as the dehydrator drying agent remains effective, before proceeding with the evacuation process. If possible, the dehydrated air should be heated to about 240°F.

Large dehydrators, suitable for preliminary dehydration of refrigeration systems, are usually available at naval shipyards and on board tenders and repair ships. After the preliminary dehydration, the remaining moisture is evacuated by means of a two-stage, high-efficiency vacuum pump having a vacuum indicator. (These vacuum pumps are available on board tenders and repair ships.)

The vacuum indicator shown in figure 5-4 consists of an insulated test tube containing a wet-bulb thermometer with its wick immersed in distilled water. The indicator is connected in the vacuum pump suction line. The suction line from the vacuum pump is connected to the refrigeration system. The refrigerant circuit should be closed to the atmosphere and the charging connection opened to the vacuum pump.

A two-stage vacuum pump is started for operation in PARALLEL so that maximum displacement may be obtained during the initial pump-down stages. When the indicator shows a temperature of about 55°F (0.43 in.Hg, absolute), the pumps are placed in SERIES operation (where the discharge from the first step enters the suction of the second step pump). The dehydration process will produce a temperature drop of the vacuum




CONVERSION TEMPERATURE °F TO ABSOLUTE PRESSURE INCHES MERCURY

| TEMPERATURE °F | ABSOLUTE PRESSURE INCHES MERCURY |
|---|---|
| 60 | 0.521 |
| 55 | 0.436 |
| 50 | 0.362 |
| 45 | 0.300 |
| 40 | 0.248 |
| 35 | 0.204 |
| 32 | 0.181 |

**Figure 5-4.—Dehydrator vacuum indicator.**

indicator as shown in figure 5-5. Readings will initially reflect ambient temperatures, then show rapidly falling temperatures until the water in the system starts to boil.

When most of the evaporated moisture has been evacuated from the system, the indicator will show a

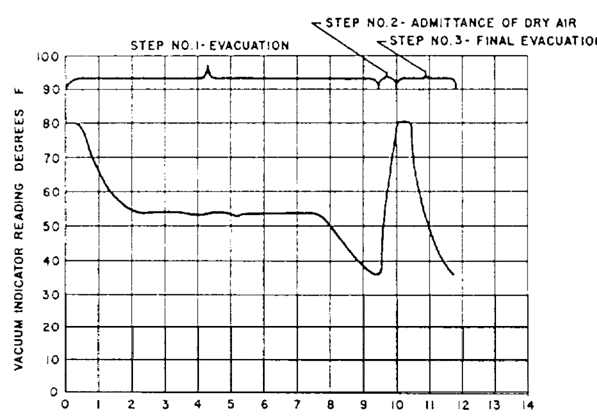



**Figure 5-5.—Vacuum indicator readings plotted during dehydration.**

decrease in temperature. When the temperature reaches 35°F (0.2 in.Hg, absolute), dry air should be admitted through a chemical dehydrator into the system at a point farthest from the pump. Continue operating the pump so the dry air will mix with and dilute any remaining moisture. Secure the opening that feeds the dry air into the system. Continue evacuating the system until the indicator again shows a temperature of 35°F. The dehydration process is complete. Close the valves and disconnect the vacuum pump.

Sometimes obtaining a temperature as low as 35°F in the vacuum indicator will be impossible. The probable reasons for such a failure and the corrective procedures to take are as follows:

- Excess moisture in the system. The dehydration procedure should be conducted for longer periods.
- Absorbed refrigerant in the lubricating oil contained in the compressor crankcase. Remove the lubricating oil from the crankcase before proceeding with the dehydration process.
- Leakage of air into the system. The leak must be found and stopped. You must then repeat the procedure required for detecting leaks in the system.
- Inefficient vacuum or defective vacuum indicator. The defective unit(s) should be repaired or replaced.

Immediately after each period of use or after the system has been opened for repairs, replace the drying agent in the dehydrator. If a replacement cartridge is not available, reactivate the drying agent and use it until a replacement is available.

You can reactivate the drying agent by removing and heating it for 12 hours at a temperature of 300°F to bake out the moisture. Place the drying agent in an oven or circulate a stream of hot air through the cartridge. Both methods are satisfactory for reactivating commonly used dehydrating agents such as activated alumina or silica gel. The specific instructions furnished by the manufacturer should be followed to reactivate special drying agents.

After reactivation, replace the drying agent in the dehydrator shell and seal it as quickly as possible. This prevents absorption of atmospheric moisture. When the drying agent becomes fouled or saturated with lubricating oil, replace it with a fresh charge, or dehydrator cartridge, taken from a sealed container.

Remember that the dehydrators permanently installed in refrigeration systems of naval ships are designed to remove only the minute quantities of moisture unavoidably introduced into the system. You must be careful to prevent moisture or moisture-laden air from entering the system.

### CLEANING THE SYSTEM

Systems may accumulate dirt and scale as a result of improper techniques used during repair or installation of the system. If such dirt is excessive and a tank-type cleaner is available, connect the cleaner to the compressor suction strainer. When such a cleaner is not available, a hard, wool felt filter about five-sixteenths inch thick should be inserted into the suction strainer screen. Run the plant with an operator in attendance for at least 36 hours or until the system is clean. The length of time required for a clean system depends upon the size and condition of the plant.

## AIR-CONDITIONING SYSTEM

Most of the information presented so far applies to the refrigeration side of a system, whether it is used for a refrigeration plant or for air conditioning. The compressor controls for both types of systems are nearly identical; however, the devices used to control space temperatures differ, The two-position dual control, called 2PD, is used for the automatic control of most shipboard air-conditioning systems.

### TWO-POSITION DUAL CONTROL (2PD)

This control is used on three types of systems:

Type 1. Systems employing a simple thermostatically controlled single-pole switch to control flow of refrigerant to the cooling coil

Type 2. Systems using reheaters, employing a ther- mostatic element actuating two interlocked switches

Type 3. Systems using reheaters in the same manner as those in type 2, with control of humidity added where specified

The type 1 system, because of its simplicity, requires little explanation. The thermostat consists of a temperature-sensing element actuating a single-pole, single-throw switch. It opens and closes a magnetic valve to start and stop the flow of refrigerant-chilled water or commercial refrigerant. This type of control is similar to the thermostatic control for the refrigeration plant. The type 1 system requires single-pole thermostats, but type 2 and type 3 systems can use two-position dual controls (2PD). The cooling switch would then be connected in the normal manner with the heating switch inoperative.

The type 2 system is most commonly used to make living and working spaces more habitable and for various types of weapons systems that require cooling. These systems often use a common cooling coil serving several different spaces. Since load changes seldom occur simultaneously, electric or steam reheaters are installed in the cooling air ducts. The cooling thermostats of the various spaces are connected in parallel so that any one of the thermostats may open the cooling coil valve.

Suppose three spaces are being cooled by a common coil. Space B in figure 5-6 has a load change and spaces A and C do not. With the coil operating to take care of space B, these spaces would become too cold for comfort. To prevent this condition, the thermostat would close the heating switch and energize the reheaters for spaces A and C.

The type 3 system is identical to the type 2 system, except that a humidistat is wired in parallel with the thermostatic heating switch. This type of system is used mostly in weapons and electronic spaces. The humidistat is set for the relative humidity desired. In most installations, it is only necessary to prevent the humidity from exceeding 55 percent. Where the humidistat is installed, an increase in temperature beyond the thermostat setting will close the thermostat cooling switch. An increase in relative humidity beyond the humidistat setting will close the heating switch and energize the reheaters.

## MAINTENANCE

Proper attention to the planned maintenance system often exposes developing troubles in time to take corrective action. Since most breakdowns occur at the most inopportune times, periodic checks and maintenance will help to avoid malfunctions.

The 2PD control system can easily be checked out in a reasonably short time. The checkout should be made at least every 3 months or more often if necessary. Inspections and checks should be made at the beginning of, and midway through, the cooling season and heating season.

You should inspect the sensing elements and remove any dust accumulations. Remove dust and dirt from thermostatic sensing elements with a soft brush. Use air to gently blow off any dust on the sensing elements in humidistats. The air will not damage the element but will remove any problem-causing dust.

Magnetic valves should be checked for operation. Be sure that they open and close completely.

Set points of the thermostats and the humidistats should be checked with a calibrated thermometer and a reliable humidity indicator.

When servicing the two-position control system, look for three possible sources of trouble:

- The sensing element and its associated mechanism

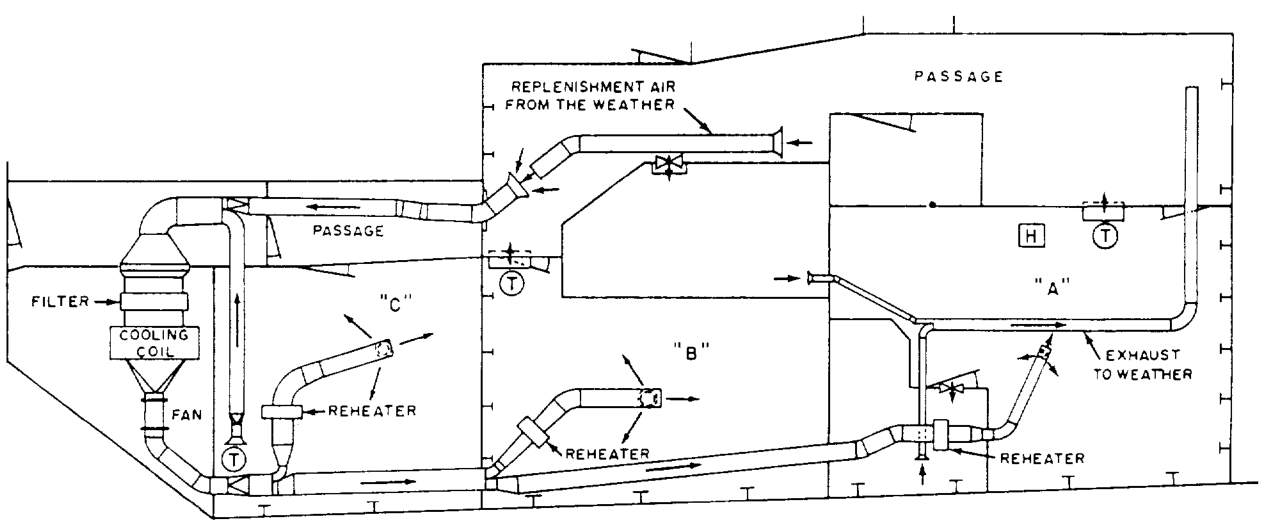



**Figure 5-6.—A typical air-conditioning system.**

- The magnetic valves that control the flow of refrigerant
- The wiring system that connects the sensing elements to the solenoids of the magnetic valves and the controller of the electric heaters

## DETECTING AND CORRECTING PROBLEMS

A number of symptoms indicate faulty operation of refrigeration and air-conditioning plants. Figures 5-7, 5-8, and 5-9 list some of the problems along with

| Trouble | Possible Cause | Corrective Measure |
|---|---|---|
| High condensing pressure. | Air on noncondensable gas in system. | Purge air from condenser |
| | Inlet water warm. | Increase quantity of condensing water. |
| | Insufficient water flowing through condenser. | Increase quantity of water. |
| | Condenser tubes clogged or scaled. | Clean condenser water tubes. |
| | Too much liquid in receiver, condenser tubes submerged in liquid refrigerant. | Draw off liquid into service cylinder. |
| Low condensing pressure. | Too much water flowing through condenser. | Reduce quantity of water. |
| | Water too cold. | Reduce quantity of water. |
| | Liquid refrigerant flooding back from evaporator. | Change expansion valve adjustment, examine fastening of thermal bulb. |
| | Leaky discharge valve. | Remove head, examine valves. Replace any found defective. |
| High suction pressure. | Overfeeding of expansion valve. | Regulate expansion valve, check bulb attachment. |
| | Leaky suction valve. | Remove head, examine valve and replace if worn. |
| Low suction pressure. | Restricted liquid line and expansion valve or suction screens. | Rump down, remove, examine and clean screens, |
| | Insufficient refrigerant in system. | Check for refrigerant storage. |
| | Too much oil circulating in system. | Check for too much oil in circulation. Remove oil. |
| | Improper adjustment of expansion valves. | Adjust valve to give more flow. |
| | Expansion valve power element dead or weak | Replace expansion valve power element. |

**Figure 5-7.—Trouble diagnosis chart.**

| Trouble | Possible Cause | Corrective Measure |
|---|---|---|
| Compressor short cycles on low- pressure control. | Low refrigerant charge. | Locate and repair leaks. Charge refrigerant. |
| | Thermal expansion valve not feeding properly.<br>(a) Dirty strainers.<br>(b) Moisture frozen in orifice or orifice plugged with dirt.<br>(c) Power element dead or weak | Adjust, repair or replace thermal expansion valve.<br>(a) Clean strainers.<br>(b) Remove moisture or dirt (use system dehydrator).<br>(c) Replace power element. |
| | Water flow through evaporators restricted or stopped. Evaporator coils plugged, dirty, or clogged with frost. | Remove restriction. Check water flow. Clean coils or tubes. |
| | Defective low-pressure control switch. | Repair or replace low-pressure control switch. |
| Compressor runs continuously. | Shortage of refrigerant. | Repair leak and recharge system. |
| | Leaking discharge valves. | Replace discharge valves. |
| Compressor short cycles on high- pressure control switch. | Insufficient water flowing through condenser, clogged condenser. | Determine if water has been turned off. Check for scaled or fouled condenser. |
| | Defective high-pressure control switch. | Repair or replace high-pressure control switch. |
| Compressor will not run. | Seized compressor. | Repair or replace compressor. |
| | Cut-in point of low-pressure control switch too high. | Set L. P. control switch to cut-in at correct pressure. |
| | High-pressure control switch does not cut-in.<br>1. Defective switch.<br>2. Electric power cut off.<br>3. Service or disconnect switch open. | Check discharge pressure and reset H. P. control switch.<br>1. Repair or replace switch.<br>2. Check power supply.<br>3. Close switches. |

Figure 5-8.—Trouble diagnosis chart-Continued.

| Trouble | Possible Cause | Corrective Measure |
|---|---|---|
| Compressor will not run (Cont'd) | 4. Fuses blown.<br>5. Over-load relays tripped.<br>6. Low voltage.<br>7. Electrical motor in trouble.<br>8. Trouble in starting switch or control circuit.<br>9. Compressor motor stopped by oil pressure differential switch. | 4. Test fuses and renew if necessary.<br>5. Re-set relays and find cause of overload.<br>6. Check voltage (should be within 10 percent of nameplate rating).<br>7. Repair or replace motor.<br>8. Close switch manually to test power supply. If OK, check control circuit including temperature and pressure controls.<br>9. Check oil level in crankcase. Check oil pump pressure. |
| Sudden loss of oil from crankcase. | Liquid refrigerant slugging back to compressor crank case. | Adjust or replace expansion valve. |
| Capacity reduction system falls to unload cylinders. | Hand operating stem of capacity control valve not turned to automatic position. | Set hand operating stem to automatic position. |
| Compressor continues to operate at full **or** partial load. | Pressure regulating valve not opening. | Adjust or repair pressure regulating valve. |
| Capacity reduction system fails to load cylinders. | Broken or leaking oil tube between pump and power element. | Repair leak. |
| Compressor continues to operate unloaded. | Pressure regulating valve not closing. | Adjust or repair pressure regulating valve. |

**Figure 5-9.—Trouble diagnosis chart-Continued.**

possible causes and corrective measures. Figure 5-10 also lists some of the problems, causes, and corrective measures and includes recommended test procedures that may be used to isolate the problems.

## SAFETY PRECAUTIONS USED WHEN HANDLING REFRIGERANTS

The following safety precautions are the minimum required when you are using refrigerants:

1. Two people must be present at all times while refrigerant is being charged into a refrigeration system. NEVER leave the area unattended while charging is in progress.

2. Ensure that ventilation in the space is adequate to keep the concentration of refrigerant below 1,000 parts per million. If necessary, use portable blowers.

3. If refrigerant is being charged into or being removed from a system, prohibit all nonessential

| TROUBLE | POSSIBLE CAUSE | TEST | REMEDY |
|---|---|---|---|
| Space temperature higher than thermostat setting | Bad location of thermostat | Carefully read temperature at the sensing element. | Relocate thermostat to a place more representa-tive of average space temperatre |
| | Thermostat out of adjust-ment or sticking | Calibrate with good ther-mometer. | Clean, adjust, or replace the thermostat |
| | Cooling coil magnetic valve not opening | Test solenoid valve for sticking valve | Replace solenoid coil. Clean valve or adjust pilots. |
| Space temperature lower than thermostat setting | Bad location of thermostat (this will also affect cooling) | Test with reliable ther-mometer at location. | Move the thermostat to a better location. |
| | Cooling coil magnetic valve stuck in open position | Stuck valve. | Disassemble and clean. |
| | Heating coil magnetic valve stuck or bad solenoid | Test solenoid. Test valve. | Replace solenoid coil. Clean the valve. |
| Thermostat or humidistat time constant too long, causing wide deviation from set point | Sensing element fouled with lint and dirt | Examine. | Clean. |
| Electric heater does not cut out | Controller contacts stuck | Use test lamp to determine. | Replace contacts, springs or other parts as found defective. |
| Electric heater does not cut in | Overheat protection not reset or defective | Place test lamp across. | Repair or replace. |

**Figure 5-10.—Trouble diagnosis chart with recommended test included.**

personnel from being in or entering the space while the refrigerant is being transferred.

4. Locate an emergency self-contained breathing apparatus for each person in the space to permit safe evacuation in the event of a large accidental leak

5. When you suspect refrigerant may be present in the atmosphere, leave the space immediately if:

- You smell something that is unusual.
- You feel light-headed.
- You feel giddy.
- You experience shortness of breath.
- You feel a tingling sensation in your fingers or toes.
- You suddenly start to feel warm.
- You experience rapid heartbeat,

6. Before using refrigerant, ensure that all hot work in the space is suspended.

7. Use chemical safety goggles or a full face shield while handling refrigerant.

8. Exercise care to ensure that liquid refrigerant does not come in contact with your skin.

9. Where available, use a halide monitor with an alarm to continuously monitor the atmosphere in the space where refrigerant is used

10. Post a caution sign in the area to read as follows:

**CAUTION**

No open flame, smoking, or welding. Do not enter without testing the air for refrigerant.

11. Establish and document emergency rescue procedures to ensure all personnel can be safely removed from potentially hazardous exposures.

## SUMMARY

This chapter has given you some information on the construction and maintenance of refrigeration and air-conditioning equipment. A helpful chart for the detection and correction of operating difficulties was provided. While the chapter was not intended as a substitute for information found in the maintenance manuals, it should help to identify the correct procedures to safely inspect, repair, maintain, and troubleshoot refrigeration and air-conditioning systems. If you have any questions pertaining to performing routine maintenance on refrigeration and air-conditioning plants, reread this chapter or refer to your specific manufacturer's manual.